

New hypotheses on the maximum damage area of the 1356 Basel earthquake (Switzerland)

Jérôme Lambert^a, Thierry Winter^{1a}, Thomas J.B. Dewez^a, Philippe Sabourault^a
^a*Bureau de Recherches Géologiques et Minières, B.P. 6009, F - 45060 Orléans cedex 2, France*

Abstract

This paper revisits the historical chronicles traditionally used to define the maximum damage area generated by the 1356 Basel (Switzerland) earthquake, one of the largest and most damaging intra-plate earthquake ever known in Europe. This work was prompted by a little known historical study detailing the castles in existence at the time of the earthquake and mentioning whether they suffered damage or not during the quake. This new data set suggests that a few damaged castles assumed to be situated in French Sundgau were probably ill located. Starting from the original historical chronicles, we propose new locations for these castles. Applying the hypothesis that chroniclers listed the damaged castles as if following an itinerary, we found localities where castle ruins are still in place today, and were bearing similar names to the inappropriately located castles. The new damage distribution of the 1356 Basel earthquake is now more compact and concentrated around Basel. To extend the value of this new interpretation, we modelled the fault and the earthquake parameters that generated the damage with Boxer, a macroseismic intensity inversion software. The modelled earthquake has a magnitude of 6.2 and was hosted on a modelled fault striking ENE-WSE. The distribution of these 650 years old seismic damages, however, only recounts the cumulated effects of two main shocks and about a dozen aftershocks. Therefore substantial ambiguities remain on the field identification of the seismogenic fault.

1. Introduction

On October 18th 1356, the Basel region was heavily damaged by one of the strongest earthquakes ever felt in continental Europe. This event was reported in Paris and Prague and within a radius of 500-km around Basel (Mayer-Rosa and Cadiot, 1979). Chroniclers from the 14th to the 16th centuries produced several lists of castles supposed to have suffered from, or even possibly having been destroyed by the earthquake. Müller (1956) attempted to associate these castles with present-day localities, and his work has now become the reference on the matter. Based on this work, Mayer-Rosa & Cadiot (1979) delimited an epicentral area resembling roughly a 60 by 40 km ellipse trending WNW-ESE and centred a few kilometres to the south of Basel (Figure 1). Meyer (1990) rather quotes that the area of maximum damage affected a zone as large as 50 to 70 km around Basel. The epicentral intensity of the earthquake was initially estimated at X (Mayer-Rosa and Cadiot, 1979) but Lambert (1988) preferred reducing it to VIII or possibly VIII-IX because the damages integrate the effects of two main shocks and a dozen aftershocks, all occurring within 48 hours. More recent work ascribed a magnitude of 6.2 to the event (Levret *et al.*, 1994).

The maps of damage distribution rely on the interpretation of seven historical chronicles written between the 14th and 16th centuries. These documents simply enumerate the names of damaged castles, partially copying one another, and mention a variable number of castle names. Since many of these castles have totally disappeared today, there is debate over their location.

In the macroseismic map presented by Mayer-Rosa and Cadiot (1979) and relying on Müller's castle locations (1956), the distribution of damages is focused on Basel, the Blauen and Hauenstein areas of Switzerland (Figure 1). Surprisingly, seven damaged castles are also located in northern French Sundgau (Figure 1 and 2). Three arguments however suggest that these castle locations might be erroneous. Firstly, there appear to be a large damage gap between northern French Sundgau and the epicentral area but these authors do not present much data for that region (Figure 1). Meyer (1981) studied thoroughly the local history of a series of localities in the heart of Sundgau and noted that many did not report any damage from the earthquake (Figure 2). This tends to show that the absence of damages in the heart of Sundgau is not due to a lack of record, but rather to a lack seismically induced destruction. The second argument for questioning damages in northern French Sundgau is that for 4 out of 7 castles allegedly

*corresponding author. Tel.: +33-2-3864-3434 - *E-mail address*: t.winter@brgm.fr

located there (Hagenbach n° 22, Montreux-le-Château n° 27, Heidweiler n° 31 and Altkirch n° 32, see Figure 2 and Table 1), there was no damage actually recorded by Meyer (1981) in these localities. Third, destruction due to localised shaking amplification is unlikely in these sites because Mulhouse did not suffer significant damage despite being largely established on amplification-prone

Quaternary sediments. Contemporaneous documents report that Mulhouse inhabitants spontaneously helped rebuilding Basel, which is the evident sign that they did not have to rebuild or heavily repair their own city. With these three arguments, it appears fundamental to reconsider the robustness of all castle locations starting from the original documents and search for plausible alternative locations if necessary.

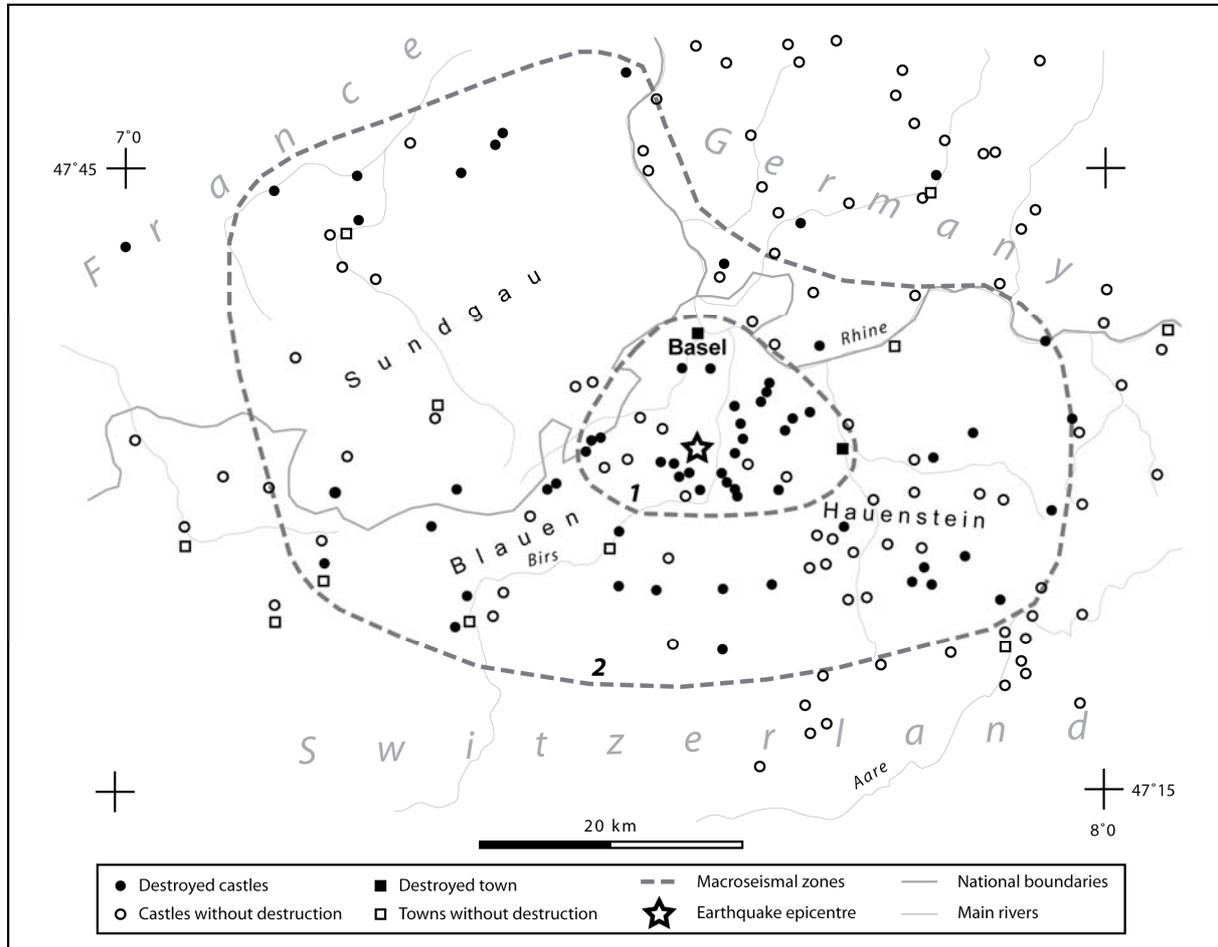


Figure 1 : Distribution of damaged castles due to the 1356 Basel earthquake sequence after Mayer-Rosa & Cadiot (1979). Note the strange northwards extension of the macroseismic zone 2 and the absence of damages in the heart of Sundgau. We make this our main argument to discuss the location of the seven castles found along the northern border of this macroseismic zone.

This paper critically re-examines the locations given to castles reported damaged by the 1356 Basel earthquake, and further builds on this analysis to suggest possible seismological parameters of the fault having generated the earthquake. In detail, we firstly review and cross-compare the historical chronicles from which modern interpretations were derived. Emphasis is put on examining the number, names and spelling of the castle reported damaged by the earthquake. This is to help assessing whether historical chronicles are trustworthy reports of the damages. Secondly, a methodology is established based on the sequence of castle names listed in the chronicles. This methodology attempts to establish whether current castle locations are realistic. The association of castle names and locations is then systematically screened. If locations appear doubtful,

we suggest alternative locations where the methodological criteria are met. Finally, we propose possible seismogenic estimates for the earthquake fault using the new damage location data set and BOXER, an inversion model designed to retrieve seismogenic parameters from a set of intensity distribution.

2. Historical sources of data

The two first historical documents to mention the damages caused by the Basel earthquake are only of limited use. Closener (1362) cites that 60 castles were damaged by the quake, but no name was mentioned explicitly, while von Nuwenburg (1368) signals that only 40 castles were damaged, but still does not mention their names. The reason why von

Nuwenburg (1368) only cites a figure of 40 castles instead of 60 is unclear.

It is only with Müller's chronicle (1375), 22 years after the event, that a first list of damaged castles is drawn. Later on, six others authors compiled similar lists: Appenweiler in 1471, Scholoder in 1525, Münster in 1544, Stumpf in 1548, Tschudi in 1570 and Wurtisen in 1580. These are the only sources that explicitly list

castle names damaged by the 1356 Basel earthquake. At this stage, the reader should note the difference between Müller (1375), the 14th century chronicler who produced the first list of damaged castles, and Müller (1956), the 20th century historian who attempted to associate these names with present-day localities. A systematic reference to the date of publication will be made so as to avoid confusion.

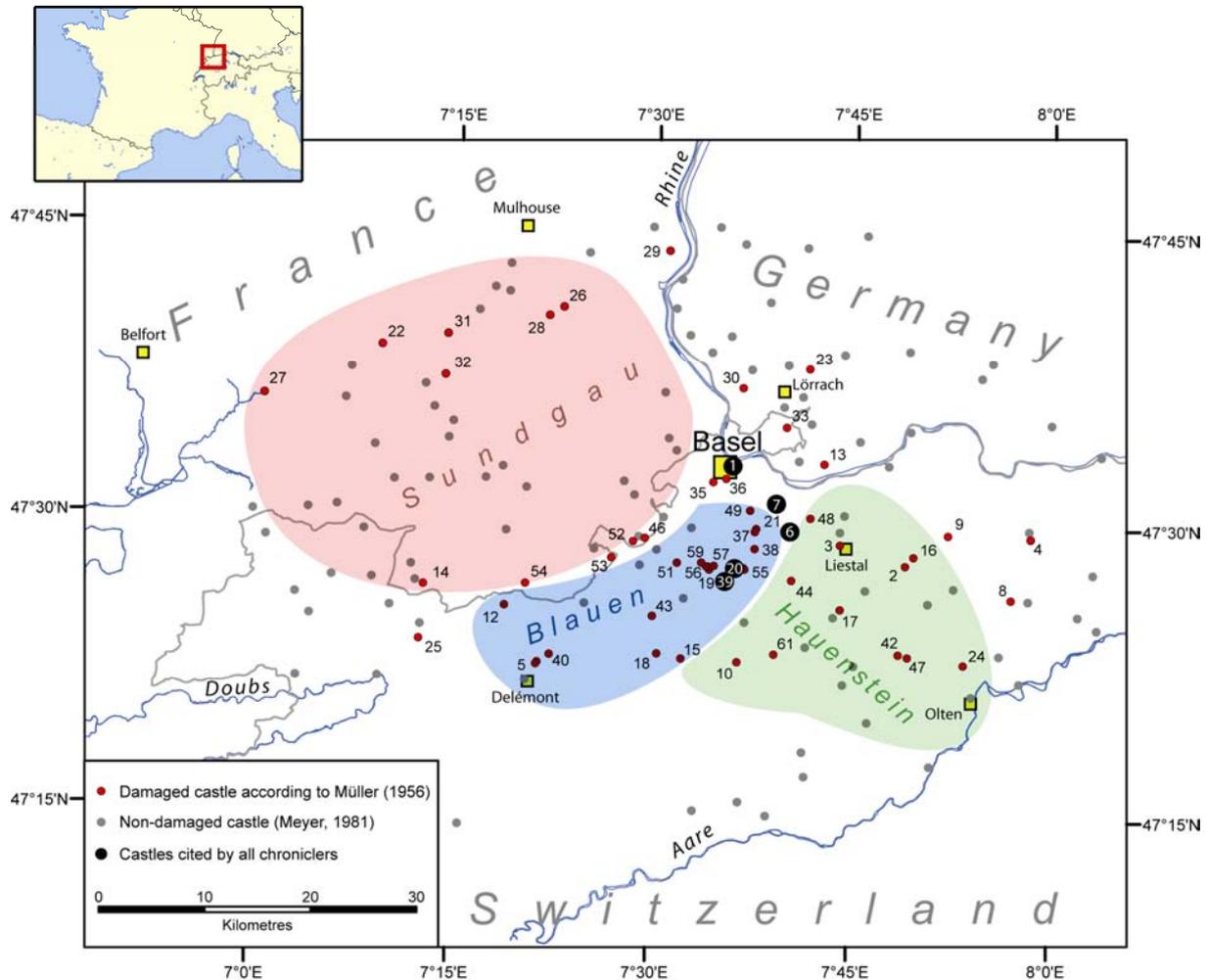


Figure 2: Distribution of damaged and non-damaged localities compiling Müller's castle locations (1956), and Meyer's (1981) additional damage/non-damage information. Refer to Table 1 to match index castle number with castle names. Black circles identify the localities common to all historical chronicles. One notes the absence of damage at the heart of Sundgau and the distance of castles 27, 22, 31, 32, 28, 26 and 29 in Sundgau with the epicentral Blauen and Hauenstein areas.

Appenweiler's chronicle (1471), added in the Universal Saxon Chronicle, was written more than a century after the earthquake. This author lists 19 damaged castles, but only seven of them are common with Müller's list (1375). In addition, the sequence in which Appenweiler (1471) enumerates the castles is clearly different from that of Müller (1375). These arguments suggest that both chronicles are independent (Table 1). Fifty years later, Scholoder (1525) listed 44 castles, but nearly reproduced Müller's list (1375) apart from Reichenstein (n° 21) and Landser (n° 26) (see castle index number in Table

1 and locations in Figure 2); he added two castles from Appenweiler's list (Landskron, n°46, and Munchenstein, n° 49; Table 1) and completed the list with 6 additional names: Achenstein (n° 41), Laufen (n° 3), Büren (n° 44), Aesch (n° 45), Eptingen (n° 47) and Madeln (n° 48) (Table 1). There was no explanation detailing these additions. In 1544, Münster copied sixteen of the nineteen castle names mentioned by Appenweiler (1471), and withdrew Munchenstein (n° 49), Dorneck (n° 38) and Oberäsch (n° 58) from the list (Table 1). Stumpf's chronicle (1548) contains 46 castle names compiled

from previous reports. Stumpf copied Müller's chronicle (1375) but 6 castles (Birseck n° 37, Altkilch n° 32, Bettingen n° 33, Waldkilch n° 34, Binnigen n° 35 and Gundeldingen n° 36), borrowed Appenweiler's list (1471) except 4 names (Dorneck n° 38, Froburg n° 24, Landenberg n° 60 et Oberäsch n° 58), and added 4 castle names introduced by Scholoder (1525) (Büren n° 44, Aesch n° 45, Eptingen n° 47 et Madeln n° 48) (Table 1). Tschudi's chronicle (1570) contains 46 castles also copied from previous chronicles. Tschudi used the whole of Müller's list (1375), and added the six names originally proposed by Scholoder (1525) (Achenstein n° 41, Laufen n° 43, Büren n° 44, Aesch n° 45, Eptingen n° 47 and Madeln n° 48). Finally, more than two hundred years after the earthquake, Wurtisen (1580) sampled 36 castles names from both Müller (1375) and Appenweiler (1471) and added Vorburg castle (n° 62). The originality of this chronicle resides in the order in which the castles were listed. Starting with Basel, Wurtisen (1580) then shifted to the Southwest of the damaged area and worked his way north, beyond Basel. We will come back on this chronicle in a later section.

Since they all more or less copied the chronicles of Müller (1375) and Appenweiler (1471), one can wonder why the 16th century chroniclers sometimes added or disregarded certain castles without mentioning why. The unjustified addition of damaged castles is a rather suspicious practice since the authors were not direct witnesses of the earthquake. To add these castles, the chroniclers must either have used some castle archives, which have been lost today, or have perhaps confused earthquake damages with those resulting from wars that episodically struck the Basel region during 15th and 16th centuries. The unjustified elimination of castle names is equally a strange practice. Altkilch and Mustral castles, for instance, were both ignored in the chronicles of Stumpf (1548) and Wurtisen (1580). Is this to say that these places had disappeared at the time of the chroniclers? Or were they unknown to these chroniclers? If the castles had totally disappeared before the 16th century, then Müller's (1956) subsequent association of *Altkilch* with Altkirch and *Mustral* with Montreux-le-Château in French Sundgau has to be erroneous because ruins of castles are still found there today.

From this brief examination of historical chronicles, we conclude that all 16th century chronicles were derived from Müller (1375) and Appenweiler (1471) (Figure 3), and that they contain information that are less reliable than their original sources. Transcriptions of the original chronicles by Müller (1375) and Appenweiler (1471) are presented in Appendix 1.

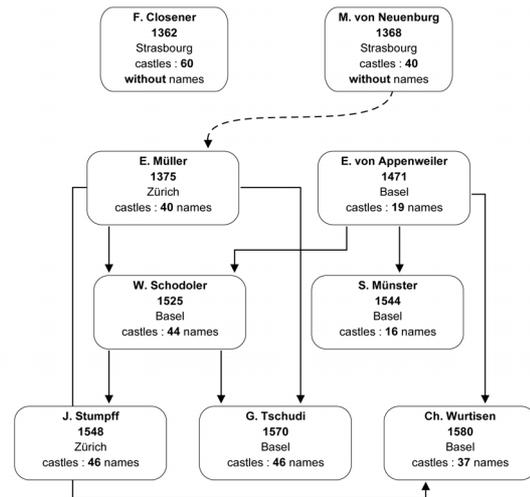


Figure 3 : Filiation tree of historical chronicles reporting the names of castles damaged by the 1356 Basel earthquakes. Note that Müller (1375) and Appenweiler (1471) do not share any similarities whereas all later chronicles derived from them.

3. Methodology for relocating damaged castles

Chroniclers reported the names of castles as they knew them at the time. Today, however, these names have evolved or even disappeared altogether. Müller (1956) was the first historian to attempt to associate the reported damages with present-day places. This exercise still serves today as reference for determining the extent and intensity of damages associated with the 1356 Basel earthquake (Mayer-Rosa and Cadiot, 1979) (Figure 1). Information derived from the history of individual localities casts doubts on previous assumptions (Meyer, 1981). Meyer (1981) described castles and buildings in existence at the time of the 1356 Basel earthquake and distinguished those that suffered earthquake-related damages from those that did not (Figure 2). The addition of new damage places across the Blauen and Hauenstein areas reinforce the observation that the quake produced the most widespread damages in the close surroundings of Basel (compare Figure 2 to Figure 1). The new set of about 100 undamaged localities also added in France, Germany and Switzerland (Figure 2) lead to a key observation. By opposition to previous assumptions, Sundgau did not suffer damages from the 1356 Basel earthquake. On the one hand, the localities of Altkirch (32), Heidweiler (31), Hagenbach (22) and Montreux-le-Château (27) in French Sundgau (Figure 4) seem to never have been damaged (Meyer, 1981) unlike what Müller (1956) implied by placing damaged castles there. On the other hand, the idea that the heart of Sundgau was protected from the quake is also reinforced, making it even more strange to infer destruction along the northern edge of Sundgau, so far from the epicentral area (Figure 4). Although one may argue that site effects could have caused castle damages at large distance from the epicentre, the fact that 4 out of the 7 castles were definitely placed in localities where the quake did not cause damage prompts us rather to question the

location strategy employed by Müller (1956). Let us examine whether one can find locations that would be located closer to the epicentre and would have a name similar to the castle's.

The methodology used to identify alternative castles locations is based on a combination of three criteria.

Criterion 1: Geographical logic

When plotting Appenweiler's list of castles (1471), it is apparent that the castles were listed in a logical geographical sequence, as if following an itinerary (Figure 5). A similar observation may also be inferred when examining Müller's castles list (1375) if we ignore Sundgau castles (Figure 6). We suggest that the castles enumerated in historical chronicles were initially reported in a geographically consistent sequence. Castles appearing suddenly far away from the rest of their sequential neighbours should be regarded as potentially ill placed (Figure 6 and 7). Unless a castle location is certified by historical sources, it should be regarded as the result of an interpretation, and could therefore be open to question. Alternative locations are preferred if they are closer to the possible listing itinerary.

Our attempt to concentrate the castles along a theoretical path is a pure working hypothesis which will tend to group damages in a smaller area. This damage clustering is consistent with seismic damage reports, where, apart from possible isolated site effects, earthquake damages are generally clustered inside a compact epicentral region. Trying to relocate castles that are demonstrably ill located is therefore reasonable.

Criterion 2: Castle name filiation

Since the names of localities and castles have changed since the 14th century, one needs to bear in mind the following causes of alterations: language-related evolutions, transcription mistakes from original handwritten documents or, more rarely, radical changes of castle names. Linguistic evolutions can be detected by comparing the different chronicles (*e.g.* Schauenburg - n° 6, Table 1 – spelled Schowenberg, Schouwenburg, Schowenburg, Schauwenburg and Schowenberg). These spelling alterations usually remain within expected linguistic variations, but following the same example, Tschudi (1570) transformed it into "Schönenberg". Such slight alteration creates an ambiguity because Schauenburg is a castle located to the east of Basel whereas a locality called Schönenberg can also be found to the SW of Basel. Further arguments are required to relocate the castle with certainty.

Castle designation may also incur more substantial variations and still reflect the same meaning. A name suffix like "fels" meaning "rock" may well become "berg" meaning "hill". In some other cases also, certain castle names have been radically modified. In a well-documented case, a castle named "Alt-Falkenstein" in the 14th century became "Klus" later on. This radical name transformation explains why

castles listed in early chronicles may remain unallocated today. Bearing these possibilities in mind, we will follow what most historians do, *i.e.* associate castle names to present-day locations where names are similar or could derive from it.

Our reinterpretation attempts to identify places bearing a name that could potentially derive from the original castle names and that are located in the close vicinity of the sequence itinerary. To circumvent the problem of spelling alterations, we compiled the various castles names and spellings encountered in the chronicles (Table 1) and examined systematically ancient maps to identify possible alternative locations.

Criterion 3: Presence of ruins

While the theoretical trip hypothesis helps identifying distant locations when toponyms are similar, it is not rare to find several localities bearing a similar name close by one another (*e.g.* Homberg n° 4, Thierstein n° 15 or Froburg n° 24, Table 1). In that case, we tried resolving the ambiguity by considering whether castle ruins have been reported in one of the localities. Although, finding ruins helped defining certain castles localities, it is far from resolving every case scenario. Some names listed in the chronicles were sometimes churches or mere *wasserschloss* (*i.e.* manors) located in the alluvial plain of rivers valleys. In such settings, both name and ruins could have totally disappeared due to more recent urbanisation.

The methodology presented above served to screen sequentially the list of damaged castles proposed by Müller list (1375). When a castle was isolated from the rest of the itinerary, alternative locations were searched for in the vicinity of the theoretical path, unless historical arguments demonstrate that the castle was appropriately located. New candidate sites are locations where the locality names are reasonably similar to the original castle names. The presence of castle ruins brings in additional evidence to support the new interpretation.

4. Critical analysis of castle location: toponymy and history

In this section, a case by case study is presented for castles with a debatable location or where alternative locations have been found. Every castle discussed below bears the name attributed by Müller (1956), the entry index quoted in Table 1, and the alternative spellings found in the different chronicles. The author index number indicates which author gave a new spelling (see right columns in Table 1). In the text, castle locations are referenced to the name of the Swiss canton (Ct.) and modern name of the locality where we suggest that they are found today. Finally, Figure 4 compiles our reinterpretations geographically.

Homberg [4] / (1,3,6 Honberg) (5:Homberg)

Homberg is a fairly common name in Switzerland; about a dozen places bear it in the Blauen and Hauenstein areas alone. Historically however, only two castles are called Homberg. One is found in Alt-Homberg (Ct. Aarau, Wittnau), the other one is in Neu-Homberg (Ct. Basel-Land, Läuelfingen) (Burgenkarte der Schweiz, 1976). Müller (1956) associated the castle cited by Müller (1375) to that of Neu-Homberg. This view is supported by Hauswirth (1971) who also thinks that Neu-Homberg was damaged during the earthquake, but Meyer (1981) preferred associating Homberg castle to that of Alt-

Homberg. According to him, Alt-Homberg castle probably collapsed during the 1356 earthquake while there is no information for the castle of Neu-Homberg.

Homberg is the first castle mentioned in Müller's list (1375) after the cities of Basel, Sissach and Liestal. Geographically, Alt-Homberg castle is relatively distant from the epicentral area. So, because Neu-Homberg (called Homberg today) near Läuelfingen (Ct. Basel-Land) is closer to the theoretical trip, we will consider that it is that mentioned by Müller (1375).

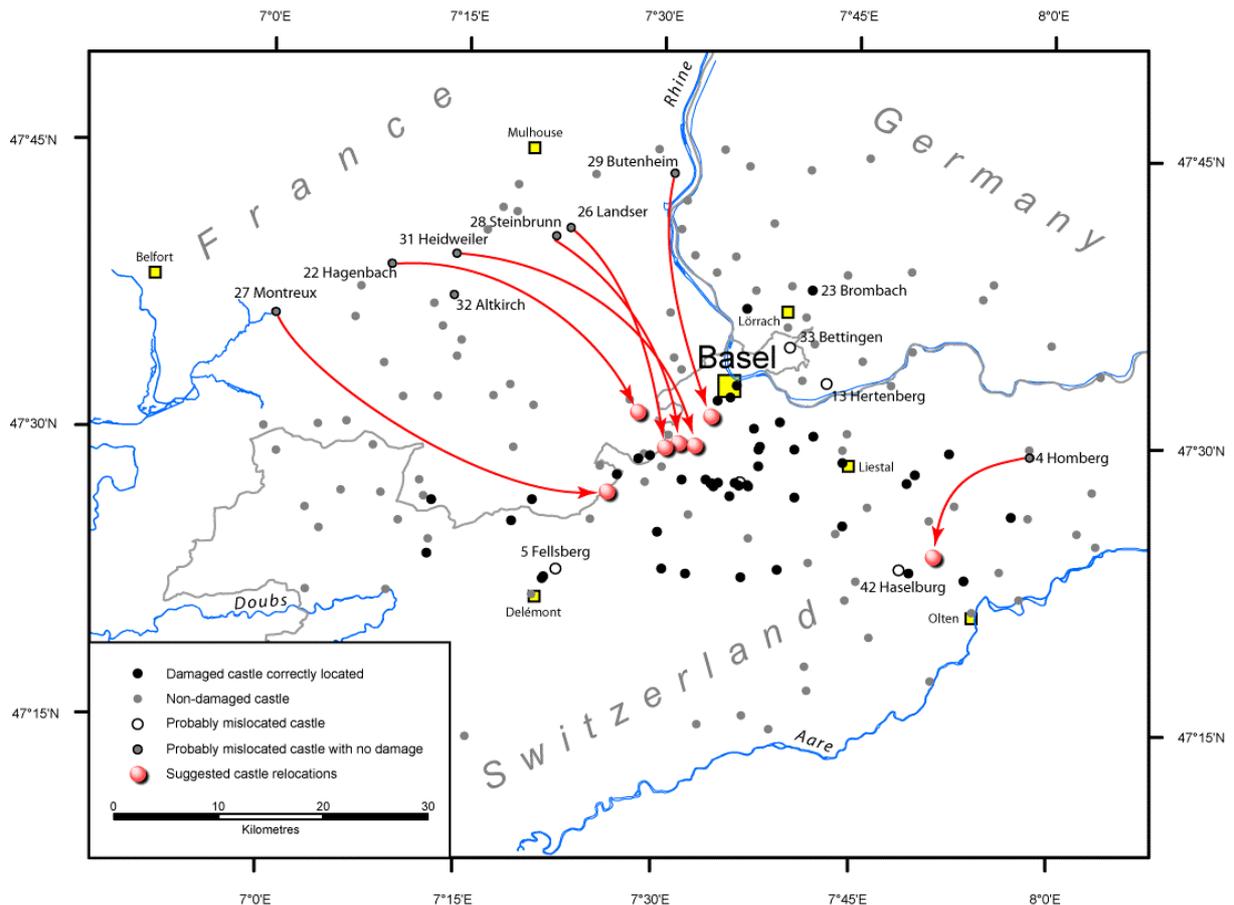


Figure 4 : Suggested castle relocations. The arrows point to the locality where castles could have been located. Note that for seven castles found to the north of Sundgau, Meyer (1981) does not signal any damages. This is the obvious sign that the 1356 Basel earthquake never affected these localities and that these castles were mislocated from the start.

Delsberg [5] [(1:Felsberg) (3:Telsperg) (5:Tellsperg) (6:Telschberg)]

According to Müller (1375), the “two castles of Felsberg” collapsed during the earthquake. In the north of Delémont (called “Delsberg” in German), Meyer (1981) notes that there was a pair of castles that are called today Vorburg and Bérudier, and that these may have been called “Delsberg” castles in the past.

To our opinion, relating Felsberg to Delsberg on the southern border of the maximum damage area appears too far geographically, and linguistically. The beginning of Müller's (1375) listing seems to radiate

from Basel outward (Figure 6). If the geographical logic holds true, the “two Felsberg castles” would thus rather be expected nearby Basel.

One cannot help but notice that in the damage area, there are only a restricted number of sites where two or three castles, very close to one another, bear the same name (*e.g.* the three Wartenberg castles, the two Schauenburg castles, the four Birseck castles). Would there be other known localities where several castles were established?

Bärenfels castle, also known as Aesch castle (commune Duggingen, Ct. Bern), is a possible candidate. Certain sources (Burgenkarte der Schweiz, 1976; Meyer, 1981), state that Bärenfels castle was

made of three distinct castles (Alte, Mittlere and Neue Burg). It is surprising that, while Müller (1375) does not mention it, five out of the six other authors cite the Aesch castle (n° 45) as being damaged by the quake. Because of this, one may speculate whether Müller's (1375) "Felsberg" castles would be those of

Bärenfels/Aesch. We prefer not reporting this information on Figure 4 and 6 because it is too speculative, but we nevertheless consider that locating Felsberg in Delémont is inappropriate.

Table 1: Synthetic table of castles damaged by the 1356 earthquake and reported in the historical chronicles known to date. The castle index number is the key serving to interpret the maps. The castle names report the original castle name considered by Müller (1956), historical variations are reported beside the main entry. In the last seven columns, the numbers represent the listing order of the castles.

Index Number	Present-day castle names according to Müller (1956) and alternative spellings in the chronicles	(1) Müller, 1375	(2) Appenweiler,	(3) Sholoder, 1525	(4) Munster, 1544	(5) Stumpff, 1548	(6) Tschudi, 1570	(7) Wurtisen, 1580
1	Basel	1	1	1	1	1	1	1
2	Sissach (1: Fillach) (6 : Sillach)	2					2	
3	Liestal (1,5: Liechstal) (2,6: Liechtstall) (7: Lieschtstal)	3		2		2	3	33
4	Homberg (1,3,7 : Honberg) (6,5: Homberg)	4		3		3	4	30
5	Delsberg (1: Felsberg) (3:Telsperg) (6,5:Tellsperg) (7:Telschberg)	5		4		4	5	2
6	Schauenberg (1,5: Schowenberg) (2: Schouwenburg) (3,4 : Schowenburg) (5:Schowenberg) (6 : Schönenberg) (7:Schauwenburg)	6	2	5	2	5	6	21
7	Wartenberg (1,3,4,5,6,7 : Wartenberg) (2 : Warttemberg)	7	3	6	3	6	7	22
8	Kienberg (1,6)	8					8	
9	Farnsburg (1: Varnspurg) (3:Varsberg) (5,7:Farnsberg) (6: Varspurg)	9		7		7	9	32
10	Gilgenberg (1,5,6,7) (3:Dilgenberg)	10		8		8	10	20
11	Munchsberg (1: Münchberg) (3,6 : Munchsperg) (5:Munchsberg) (7: Monschsberg)	11		9		9	11	12
12	Lowenburg (1,3,6: Löwenberg) (5,7: Louwenberg)	12		10		10	12	4
13	Hertenberg (1: Hertensperg) (3,5,6,7 : Hertenberg)	13		11		11	13	34
14	Morimont (1,7: Mersperg) (5: Mersberg) (3, 6: Morsperg)	14		12		12	14	5
15	Thierstein (1,3,5,6 :Tierstein) (7:Thierstein)	15		13		13	15	7
16	Bischofstein (1) (3,5,6 :Bischoffstein)	16		14		15	16	
17	Wildenstein (1,3,5,6,7)	17		15		16	17	28
18	Neuenstein (1:Niuwen) (3:Tuwen) (5: Nuwenstein) (6: Nuwen) (7: Neuwenstein)	18		16		17	18	8
19	Ergenstein (1,5,6: Engenstein) (3: Engunstein)	19		17		18	19	
20	Angenstein (1,2,4) (3: Augustein) (5,7: Hangestein) (6: Ougustein)	20	7	18	5	19	20	13
21	Reichenstein (1,2,4,6: Richenstein) (5:Rychenstein) (7:Reichenstein)	21	5		4	20	21	15
22	Hagenbach (1,3,5,6)	22		20		21	22	
23	Brombach (5,6) (1: Bronbach) (3,6 : Branbach)	23		21		22	23	36
24	Froburg - near Olten (1, 5,6,7) (3:Fronburg)	24		22		23	24	31
25	Asuel (Hasenburg:1,6,7)	25					25	24
26	Landser (1: Landeser) (5: Landosser) (6: Landeser) (7: Landesehr)	26				25	26	23
27	Montreux-le Château (1: Müstral) (3,5,6 : Munstral)	27		25		26	27	
28	Steinbrunn-le-Bas (1,3,5,6 : Steinbrunnen) (7: Steinbrunn)	28		26		27	28	25
29	Butenheim (1,5: Büttingen) (3,6: Butingen)	29		27		28	29	
30	Oetlikon (1: Edlikon) (3: Oetlicken) (5: Oetlickon) (6 : Ottlikon) (7: Ottliken)	30		28		29	30	35
31	Heidweiler (1:Hertwilen) (3,6: Hertwiller) (5: Hertwyler) (7: Heitweiler)	31		29		30	31	27
32	Altkirch (6) (1: Altkilch) (3: Altkilch)	32		30			32	
33	Bettingen (1: Bietkôn) (3: Bettiken) (6: Bietikon)	33		31			33	
34	Waldkilch (1,3,6)	34		32			34	
35	Binningen (1: Brünigen) (3: Buringen) (6: Büningen)	35		33			35	
36	Gundeldingen (1: Guntoltingen) (3,6: Gundelltingen)	36		34			36	
37	Birseck (7) (1,3: Brisegg) (6: Birsegk)	37		35			37	16
38	Dorneck (1,3: Dornegg) (2: Dornach) (5,6: Dornegk)	38	6	36		31	38	
39	Pfeffingen (1,2,4) (3: Pfeffikken) (5,6,7: Pfäffingen)	39	10	37	7	32	39	9
40	Soyheres (1,5,6: Sengûr) (3: Sengen)	40		38		33	40	
41	Achenstein (3)			19				
42	Haselburg (3,5)			23		24		
43	Laufen (3)			24				
44	Büren (3,5) (6 : Bürren) (7: Beuren)			39		34	41	18
45	Aesch (3: Esche) (5: Esch) (6 : Driesche)			40		35	42	
46	Landskron (4,5) (2: Lansskron) (3: Landsskron) (6: Landtskron) (7: Landtsron)		15	41	12	36	43	14
47	Eptingen (3,5,6,7)			42		37	44	29
48	Madeln (3,5,6: Madlen)			43		38	45	
49	Munchenstein (2,3,5,6) (7: Monchenstein)		4	44		39	46	17

50	Löwenstein (5)					14			
51	Furstenstein (2,4,5)			14		11	40		
52	Waldeck (4) (2: Waldek) (5: Waldegk)			16		13	41		
53	Biederthal (4) (2: Biedertal) (5,7: Biederthan)			17		14	42		26
54	Blochmont (7) (2,4,5: Blochmund)			19		16	43		6
55	Bärenfels (4) (2: Berenvels) (5,7: Berenfelss)			8		6	44		10
56	Schalberg (2,4,5,6: Scholberg)			11		8	45		11
57	Klus (2) (4: Cluoss) (5: Kluss)			13		10	46		
58	Oberäsch (2: Obrenechs)			9					
59	Froburg - near Aesch (2,4)			12		9			
60	Landenberg (2,4)			18		15			
61	Ramstein (7)								19
62	Vorburg (7)								3

Hertenberg [13] [(3,5,6,7) (1: Herttensperg)]

Hertenberg castle is presumed to be located in Baden-Württemberg (Germany) ca. 10 km East of Basel. According to several sources (Burgenkarte der Schweiz, 1976; Meyer, 1981; Müller, 1956), Hertenberg castle was damaged by the quake. When replacing this castle in sequence, however (Figure 6), it falls very far away from its sequential neighbours (Lowenburg n° 12 and Morimont n° 14). No alternatives were found in the vicinity of these neighbours. Even though we still regard the original position as debatable, for now, we prefer keeping at its present location, because historical studies are positive about it.

Hagenbach [22] [(1,3,5)]

According to Müller (1956) and Meyer (1981), Hagenbach castle would be located in France, 16 km South-west of Mulhouse and 34 km north-west of Basel. The distance of this castle to the epicentral area is rather large considering the absence of damage otherwise reported by Meyer (1981) in Sundgau. One may wonder if Hagenbach castle could once have been called “Hagenthal”; the suffixes “bach”, meaning “brook”, and “thal”, meaning “valley”, correspond virtually to the same meaning and could be interchanged. On Sanson’s historical maps (1703), for instance, a village called Hagenthal is mapped where Hagenthal-the-Bas is currently established (France, 9 km Southwest of Basel), but the nearby town of Biederthal was then called “Beitenbach”. This coincidence suggests that both name endings are interchangeable. It would thus be possible to relocate Hagenbach castle to Hagenthal-le-Bas, where Meyer (1981) also incidentally reported the presence of a castle.

Brombach [23] [(5,6), (1: Bronbach) (3: Branbach)]

According to Meyer (1981), Brombach castle is located in Germany, 12 km north-east of Basel and was rebuilt after the 1356 earthquake. On Sanson’s map (1703), for instance, a place called “Brumbach” is also found in the surroundings of Burg-im-Leimental (Ct. Bern), 12 km to the West of Aesch. This alternative location is both inside the epicentral area and along the logic of Müller’s (1375) itinerary. Despite these arguments, we will leave this castle where it is because Meyer (1981) was fairly definite about the identification.

Froburg [24] [(1,2,4,5,6,7), (3: Fronburg)]

Froburg castle is a difficult case because two distinct castles bear that name at the time of the earthquake. The first one is found near Olten (Ct. Solothurn) (Meyer, 1981; Müller, 1956) while the second one, reported as Froberg on Swiss maps (e.g. Burgenkarte der Schweiz, 1976) is located near Aesch (Ct. Basel-Land) (location mentioned only in Meyer, 1981). If both castles existed before the earthquake, which one did the chroniclers intend to cite?

According to Müller (1956) and Meyer (1981), Froburg near Olten was destroyed in 1356. On the contrary, Müller (1956) ignores the existence of Froburg near Aesch, while Meyer (1981) does not give any information about damages in that location. However, when considering the logic behind Appenweiler’s castle sequence, Froburg near Aesch is clearly the only possible candidate (Figure 5). From this, could one reasonably conclude that two Froburg castles were destroyed? Following Müller (1375), it is not obvious which castle was intended, although that of Aesch would appear much closer to its relocated sequential neighbours (Figure 6). On the other hand, Wurtisen (1580) was most likely thinking about Froburg near Olten because it is situated along his itinerary (Figure 7). At the time of writing this paper, we prefer leaving the debate open and choose to keep Müller’s (1375) and Wurtisen’s (1580) “Froburg” to Froburg near Olten, as previously assumed. Nevertheless, a new entry (n° 59, Table 1) must be created for Froburg near Aesch to agree with Appenweiler’s chronicle (1471).

Landser [26] [(1: Landeser) (5: Landosser) (6: Landesern) (7: Landesebr)]

According to Müller (1956) and Meyer (1981), Landser castle is located in France, 8 km south of Mulhouse and was ruined by the 1356 earthquake. We think however that this conclusion is incorrect.

During the 14th century, one of the most important medieval fortresses in this region is that of “Landsron”, sometimes called “Landseron” on historical maps (e.g. Cassini de Thury, 1763), or “Landskron” (n°46) (Appenweiler, 1471; Münster, 1544; Scholoder, 1525; Stumpff, 1548; Tschudi, 1570; Wurtisen, 1580). Since Landskron is known to have been heavily damaged during the 1356 earthquake (e.g. Appenweiler, 1471) it very surprising that Müller (1375) would have forgotten to cite it. It is probable that a transcription mistake rather made “Landseron” become “Landser”. This error, possibly committed by Müller (1375) himself, could then have propagated to all successive 16th century chroniclers who copied

him. We consider that Landser (n°26) is the same castle as Landskron (n°46) and is located along the Franco-Swiss border about 15 km SW of Basel (Figure 6B).

Montreux-le-Château [27] [(1: *Mustral*)(3,5: *Munstral*)]

Müller (1956) associated Mustral with the present-day Montreux-le-Château (France) because this locality used to be called ‘Munsterol’ in the past. We doubt that this association is correct because of the significant distance between Montreux-le-Château and the epicentral area. Remarkably, Meyer (1981) does not present any data about this castle.

Although Mustral remains undiscovered to date, one may speculate on a linguistic connection between Mustral and names like “Metzeran”, “Metzeray”, “Metzerlin” or “Metzerlen” found on old maps (e.g. Sanson, 1703). In canton Solothurn, 1,5 km east of the present-day village of Metzerlen, we consider that “Rothberg” castle may correspond to Mustral castle because it is located very near to its sequential neighbours, the name filiation is acceptable and ruins of a castle remain today.

Steinbrunn [28] [(1,3,5: *Steinbrunnen*) (6: *Steinbrunn*)]

According to Müller (1956) and Meyer (1981), Steinbrunn castle is that of Steinbrunn-le-Haut (France), 8 km south of Mulhouse and 22 km north-west of Basel. It was rebuilt after the damages due to the 1356 earthquake. Although one cannot totally discard possible site effects because the castle was a *wasserschloss* surrounded by moats, this location seems too remote from the epicentral region.

Several other location hypotheses can be considered. On ancient maps, there is no mention of Steinbrunn or Steinbrunnen in Switzerland but on the modern 1/25.000 Swiss topographic maps (sheet Arlesheim) a locality called “Steinbrunnen” is found 700 m to the SE of Bärenfels castle (n°55). Alternative locations for this castle may be located in the close vicinity of villages with names ending in “Brunn”. These are mostly concentrated in the direct surroundings of Hagenthal-Le-Haut and Liebenschwiller villages (e.g. Heiligenbrunn, Kaltbrunn...). Etymologically, Steinbrunnen means “springs of the Stein brook”. One notes that a brook called Steinen flows in Binningen. Could there be a connection between this and the castle mentioned? Yet another suggestion, “Stein” castle, which became today’s closter of Mariastein (Ct. Solothurn), is located 1 km north of Rothberg castle. This is where we tentatively plotted the relocated castle.

Butingen [29] [(1,5: *Buttingen*) (3: *Butingen*)]

According to Müller (1956) and Meyer (1981), probable damages were due to the 1356 earthquake in Buttenheim (France), 13 km east from Mulhouse, 21 km north from Basel. To our opinion, the hypothesis connecting Butingen to Buttenheim in Alsace is too far afield from the epicentral area.

“Buttingen” or “Butingen” may reasonably derive into “Botingen” which is clearly identified on historical maps (e.g. Mercator, 1630) and corresponds to the present-day Botmingen (Ct. Basel-Land) located 4 km south of Basel. According to several sources (Burgenkarte der Schweiz, 1976; Hauswirth, 1971; Meyer, 1981), Botingen castle is clearly identified as a “Wasserschloss” built in 13th century.

Oetlikon [30] [(1: *Etlikon*) (3: *Oetlicken*) (5: *Oetlickon*) (6: *Ottliken*) (7: *Ottliken*)]

This castle could be located in various places. According to Meyer (1981), in the village of Otlingen in Germany, 5 km north of Basel, a castle named “Otlakon”, was first mentioned in the 13th century. That castle was damaged during the 1356 earthquake. Rebuilt, its name is today “Friedlingen”.

On historical maps, one can find two places named “Otlingen”. These names evolved today into the German “Otlingen” site cited above and the French Olingue village (7 km west of Landskron). But, according to Meyer (1981), the association between Olingue and Otlingen castles is perhaps inappropriate. To our opinion locating Oetlikon in Germany seems also somewhat unreliable.

A third hypothesis relating Oetlikon to the present-day Ettingen, near Aesch could be put forward. This site, which was previously called Eticken or Oettigen, may have a similar linguistic origin. Given the number of potential candidate and the uncertainty of the interpretations, we did not plot it on the maps but regard that location as questionable.

Hertwiler [31] [(1: *Hertwiler*) (3: *Hertwiller*) (5: *Hertwyler*) (6: *Heitweiler*)]

Müller (1956) associates this place to Heidweiler castle located in France, 12 km south-west of Mulhouse, 28 km north-west of Basel. According to Meyer (1981), there is no data concerning damages due to the 1356 earthquake in Heidweiler castle.

Müller’s (1956) connection between “Hertwiler” and “Heidweiler”, transforming “Hert” into “Heid”, is linguistically debatable, whereas swapping “Her” for “Der” seems rather more plausible. With this alternative, “Hertwiler” turns into “Derwiler”, which is a village visible on historical maps (e.g. Mercator, 1630) inside the epicentral area. Today, the village of Derwiler became “Therwill” (Ct. Basel-Land, 7 km south of Basel) where a castle has been known since 1255.

Altkirch [32] (6) (1: *Altkilch*) (3: *Altkilch*)

According to Müller (1956), the castle of Altkirch is located in France in the town of the same name, 15 km Southwest of Mulhouse, 28 km Northwest of Basel. Meyer (1981), however, does not mention any seismic damage in the present-day village of Altkirch. Again, the long distance between Altkirch and the epicentral area makes it a debatable location. We think that “Altkilch”, meaning literally “old church”,

should rather be located in the vicinity of Basel, but we lack arguments to plot it on the maps.

Bettingen [33] [(1: *Bietkon*) (3: *Bettiken*) (6: *Bietikon*)] Müller (1375) evokes two castles in Bietkon. According to Müller (1956), Bettingen would be found 6 km east of Basel (Ct. Basel-Stadt). Meyer (1981) does not explicitly discuss Bettingen castle but rather the St-Chrischona church outside the locality of Bettingen. St-Chrischona is the eldest church of Switzerland and was damaged by the 1356 earthquake. It is worth noting that the most recent historical studies (*e.g.* Historical dictionary of Switzerland) do not report the existence of a castle in Bettingen. From a linguistic point of view, Bietkon could perhaps be associated with the 13th century castle of Benken (Ct. Basel-Land, commune Biel-Benken). With the current knowledge, we regard the present association of Bettingen as doubtful but cannot offer another firm interpretation.

Waldkilch [34] [(1, 3)]

Waldkilch remains undiscovered today and does not appear on as such historical maps. On the other hand, a place called *Weiskilch* is often plotted on historical maps only a few hundred meters west of Benken (see Bettingen) (*e.g.* Jaillot, 1706; Sengre, 1692). Could these be the same place?

Klus [57] [(2),(4 : *Cluoss*), (5 : *Kluss*)]

According to Müller (1956) and Meyer (1981), this castle is that of Alt-Falkenstein near Balsthal (Ct. Solothurn). Meyer (1981) wrote that Klus castle suffered little damage from the 1356 earthquake. Since Appenweiler (1471) is the first author to cite this castle, the most likely location is rather in a place called today 'Clus or Chlus', 1 km west from Aesch (Ct. Basel-Land), which is clearly situated along Appenweiler's itinerary. This interpretation is also corroborated by Mercator's map (1630).

Landenberg [60] [(2,4)]

This castle remains undiscovered today. However, when considering Appenweiler's itinerary (1471) (Figure 5), Landenberg castle would be expected in the surroundings of Biederthal and Blochmont. It might correspond to the present-day Burg-im-Leimental castle (Ct. Bern).

To sum up these interpretations, the arguments presented to locate ancient castle names may sometimes appear subjective. Two key elements should nevertheless be recalled. Firstly, Müller's location exercise (1956) relies mostly on name resemblance between a castle and its presumed present-day location. Applying the same paradigm, we discovered alternative possibilities, which are equally valid from a pure linguistic point of view. Secondly, we support our argumentation with the necessity of finding candidate sites within the epicentral area because remote destruction caused by

site effect do not seem very likely for this earthquake. In the end, the new locations reproduce a compact distribution of castles around the Blauen and Hauenstein areas and respect the absence of damage reported by Meyer (1981) (Figure 4).

5. Indirect validation of alternative locations

The original geographical sequence of castle (Müller, 1956) is compared with the new distribution of castles. This exercise is performed first on the castle list proposed by Müller (1375) and then on that produced by Wurtisen (1580). Our purpose here is to examine if the suggested relocations rationalise the overall castle distribution.

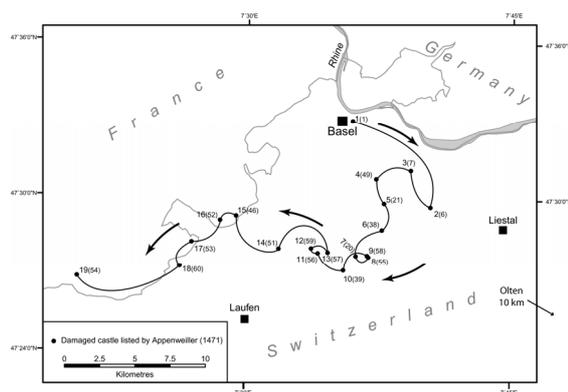


Figure 5 : Sequence of damaged castle cited by Appenweiler (1471). Starting from Basel, the sequence follows a perfect geographical logic. The first number indicates the sequential order in which Appenweiler (1471) cited the castles. The number in bracket is the index castle number to be used as entry in Table 1.

Müller's (1375) enumeration of damaged castles is organised in four successive groups.

In the first group, castles 1 to 7 are located to the SE of Basel except for that of Delsberg (n°5), which is probably inappropriately placed in Delémont (see above). Removing Delsberg from the sequence shows that this first group of castles are situated along a line going from Basel towards Olten in the SE (Figure 6). In that group, the new position of Homberg castle (n°4) in Homburg does not significantly alter this trend (Figure 6), but improves slightly Wurtisen's itinerary (Figure 7).

The second sequence comprises castles n°8 to 21 (Table 1, Figure 6). These castles correspond to a wide area confined to Switzerland and curving around Basel. The association of Herttensperg castle (n°13, Table 1) with Hertenberg (Müller, 1956) is rather distant from a hypothetical trip but we did not find any acceptable alternatives closer to Lowenburg (Löwenberg, n°12) and Morimont (Mersperg, n°14). This sequence of castle (Figure 6) does not seem to be very rational, neither before or after relocation.

The third sequence consists of 10 castles (n°22-31). According to Müller (1956), six castles were supposed to be in Sundgau, two in south-western Germany, and two in Switzerland (Figure 4). With this distribution, Müller's itinerary (1375) seems completely irrational (Figure 6A). Our alternative

locations, on the other hand, produced a much more rational sequence of castles where they all fall inside a limited geographical area along the France-Switzerland boundary.

The fourth sequence counts 9 castles (n°32-40). Altkirch (Altkilch, n°32) and Soyheres (Sengur, n°40) lie some distance away from the other castles but no other alternatives have been found.

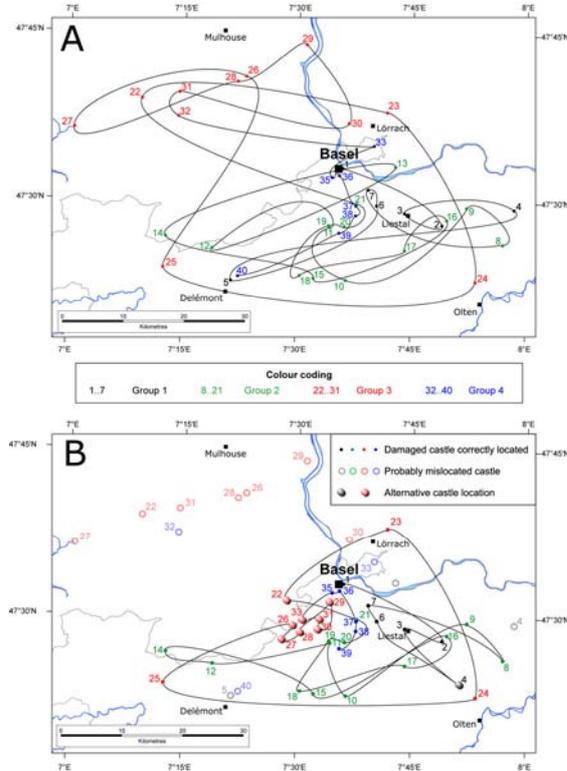


Figure 6 : Sequence of castles listed by Müller (1375). A) Itinerary connecting the castles using Müller's location (1956). B) Itinerary connecting the castles following the new interpretation. It appears that the alleged castles are all clustered in the border region between France and Switzerland. The colours represent the castle groups enumerated by Müller (1375). Rather than a strict itinerary, it seems that Müller (1375) has listed the castles following a regional logic.

The geographical logic applied to locate castles from Müller's chronicle (1375) reduced remarkably the dispersion of the third group of castles. With our new interpretation, it seems that Müller (1375) has listed castles in a regional manner more than along a linear itinerary.

Wurtisen's chronicle (1580) presents an interesting characteristic. Even though this chronicle was compiled from Müller's (1375) and Appenweiler's (1471) lists (Figure 3), it cites damages in a northward sequence, starting in the south and closing in on Brombach. In the beginning, the sequence strictly follows a geographical logic (Figure 7). The spatial arrangement breaks down, however, when the supposed Sundgau castles are entered *e.g.* Landser (n°23), Steinbrunn-le-Bas (n°28), Heidweiler (n°27) (Figure 7A). Our alternative suggestion brings these castles closer to their sequential neighbours (Figure 7B). It must be noted nevertheless that when we

considered alternative locations for castles n° 31, 35 and 36, the dispersion of the theoretical trip increases.

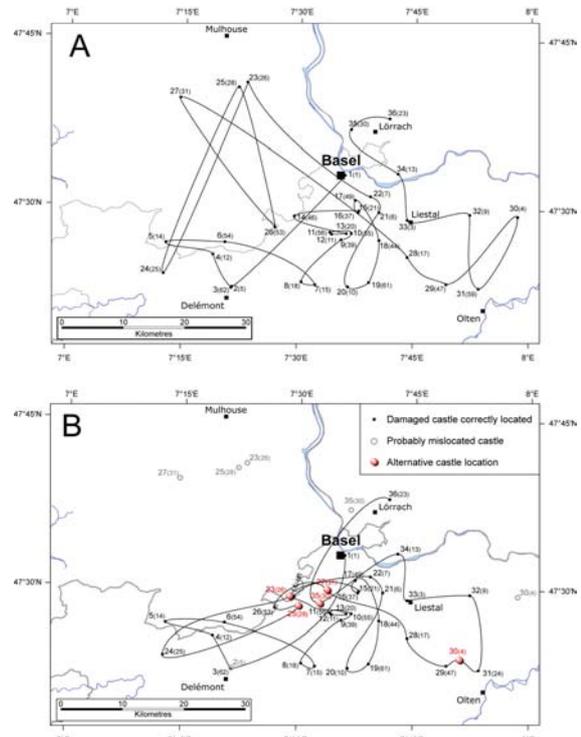


Figure 7 : Sequence of castles damaged in the 1356 Basel earthquake such as listed by Wurtisen (1580). A) Itinerary connecting the castles located by Müller (1956). B) Itinerary including new castles. Four castle relocations appear to rationalise the itinerary, but our interpretation of Oetlikon (n°30) seems inappropriate in this case.

6. Inversion of damage intensities

Up to this point, the discussion solely revolved around the likely locations of the 1356 Basel earthquake damages, but this study would not be complete without exploring the intensity of damages. SisFrance, the French online database produced by the BRGM (<http://www.sisfrance.net>), contains historical macroseismic intensity information for earthquakes felt in France since ca. 465 AD. The historical accounts contained in the database have been examined in detail for their historical accuracy and every new addition is subjected to regular quality checks required by the sponsoring institutions (EDF and IRSN). For the 1356 Basel earthquake, SisFrance indicates a likely epicentre location that was derived from an interpretation of the maximum damage area (Table 2).

Recent advances in seismological modelling (Gasperini *et al.*, 1999) can now estimate likely seismic parameters for the fault that would have hosted it based on a distribution of damages. These seismic parameters are of the highest importance because they can enter in regional earthquake hazards scenarios.

BOXER

BOXER is a macroseismic inversion model developed by Gasperini *et al.* (1999). The software outputs the likely epicentral location, moment magnitude and fault dimensions and orientation from a set of observed intensities. The epicentral location is a function of the weighted average of reported damages; the moment magnitude (M_w) is a function of the surface area of the damaged zone and of the

epicentral intensity; length and width of the fault plane are derived from Wells and Coppersmith's empirical relations (Wells and Coppersmith, 1994) and the fault orientation is calibrated on the geographical distribution of maximum intensities (see Gasperini *et al.* 1999 for details on computational techniques).

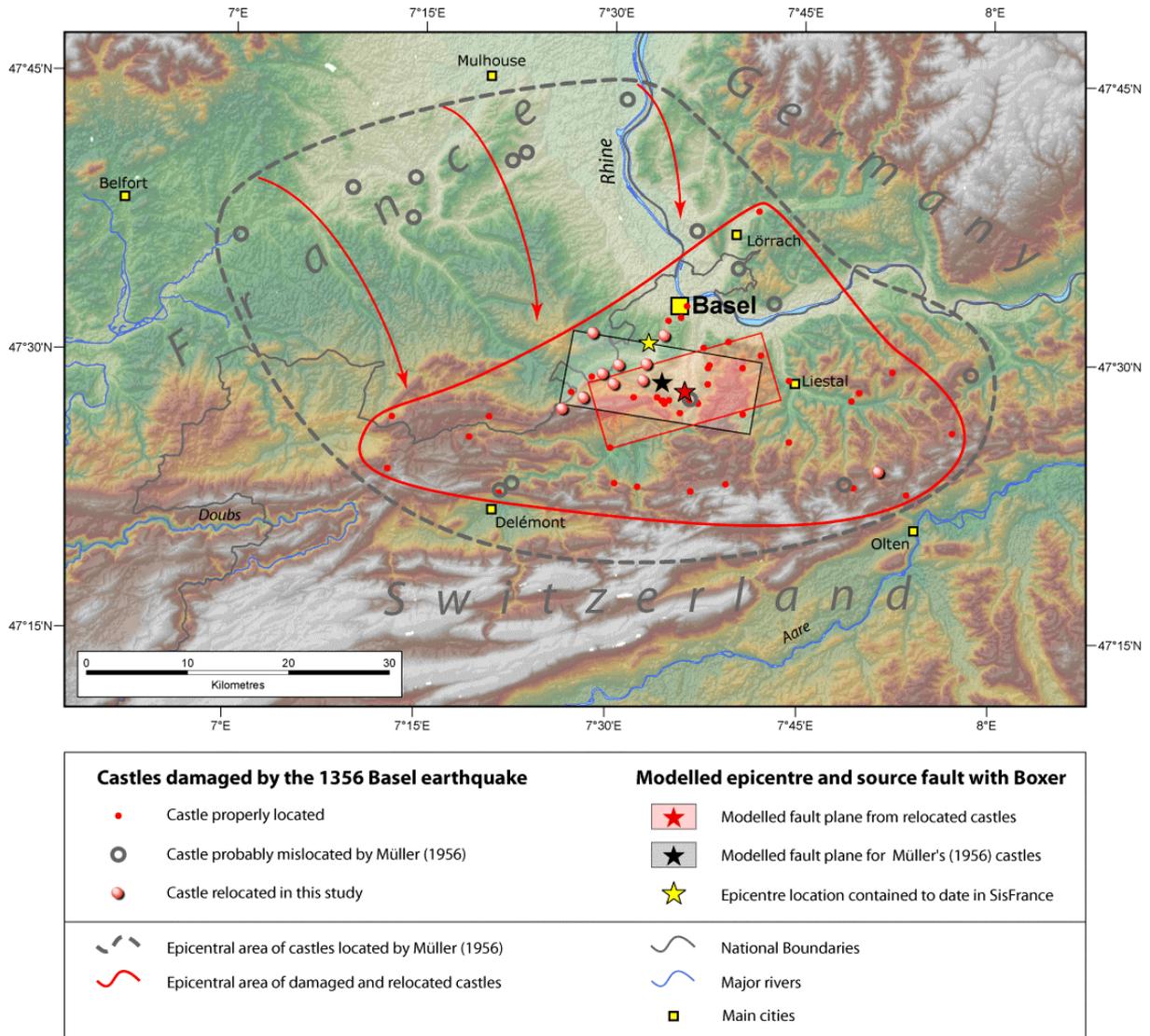


Figure 8 : Synthetic map demonstrating the reduction of the area of maximum damage. The stars show the modelled locations of epicentre and the boxes display the seismogenic fault suggested by BOXER, the intensity inversion model. The black box and epicentre is that computed on the basis of the original damage distribution (Müller, 1956). The red box and epicentre is that computed for the reinterpreted damage data set. In both cases, the modelled seismogenic fault is oriented along an E-W strike.

There are many refinements one can bring in when considering macroseismic data sets, but here since the thrust of this paper concerns the new interpretation of damage locations, we used BOXER to compare how a changing pattern of damages affects seismogenic parameters.

Intensity database

At the time of writing this paper, the SisFrance database still contains the castle locations accepted in the literature (Lambert, 1988; Mayer-Rosa and Cadiot, 1979; Müller, 1956). The intensities range from VII to VIII or IX (MSK 64). In the epicentral area, the intensities are poorly constrained, except that of Basel (Wechsler, 1987). Inversions were performed with

both far and near field intensity data disregarding possible site effects.

Experimental set-up

In the case of the original damage distribution, the coordinates of the castles correspond to those contained in SisFrance. In the new castle distribution, the location are that of the castles ruins measured either with a handheld GPS in the field or measured on the Swiss 1/25.000 topographic maps. The intensity are reported for two types of data points: i) six far field data points (Bern, Besançon, Dijon, Metz, Montbart and Strasbourg) indispensable for scaling the model in BOXER, these were kept identical for both models, ii) intensities of VIII were assigned to all the castles, and intensities of VIII or IX for Liestal and Basel.

Modelling results and discussion

Modelling results are presented in Table 2. Müller's castle distribution (1956) suggests that the 1356 Basel earthquake had a moment magnitude of 6.3, and was located on an nearly E-W-trending fault (N099°E) located less than 10 km south of Basel (Table 2). With the new castle distribution the damage area has a smaller extent explaining why the moment magnitude of the earthquake is slightly smaller ($M_w=6.2$) and the associated fault has a smaller width and length. The new epicentre is now modelled under the Birs valley on a fault oriented N073°E). Both modelled epicentres are located roughly 5 km further south than previously thought (see Table 2). Although additional work is currently done to assess modelling bias introduced by site effects, the results presented here provide first order estimates. Apparently, the fault responsible for the earthquake has a strong E-W component and is most likely located under the Blauen region.

Table 2: Fault and seismic parameters of the 1356 Basel earthquake modelled from intensity distribution with BOXER (Gasperini *et al.*, 1999). The assumed epicentre location is that contained to date in the SisFrance online database. Two experimental conditions were modelled. The first one ($n^{\circ}1$) with the castle coordinates contained in SisFrance (i.e. Müller, 1956). The second model inverted the new castle locations proposed in this paper.

The smaller extent of the relocated damage area induces a slightly small moment magnitude (6.2 instead of 6.3) and smaller fault dimensions. The new damage distribution caused the modelled fault to rotate slightly and the epicentre to shift eastward, underneath the Birs valley. Azimuths are in degrees counted clockwise from North. The dimensions of the fault planes are the length and width down dip (i.e. width of the fault plane entering inside the earth's crust). Boxer models the epicentre as being the centre of the fault plane. Latitude and Longitude are in degrees on WGS84. Note that at this stage Boxer does not resolve the dip of the fault nor the likely trace of the fault plane at the surface.

	Moment magnitude (M_w)	Azimuth (°)	Length	Width	Lat. epicentre	Long. epicentre
Assumed Epicentre in SisFrance					47.5167°	7.5500°
1. SisFrance data set	6.3	N099°E	18.8 km	10.1 km	47.4808°	7.5684°
2. Relocated data set	6.2	N073°E	17.7 km	9.8 km	47.4729°	7.5983°

The current controversy about the Basel earthquake is that two families of faults exist in that area: Rhine Graben type faults oriented NNE-SSW (e.g. Meghraoui *et al.*, 2001), and Palaeozoic structures oriented ENE-WSW (e.g. Meyer *et al.*, 1994; Ustaszewski *et al.*, submitted). It is not known which family of fault generated the quake. Both modelling results, before and after castle relocation, however, seem to indicate that an ENE-WSW-striking fault generated the observed damage distribution. This piece of evidence alone cannot resolve the controversy, however. Historical reports recount that the quake was in fact made of a sequence of two main shocks (Lambert, 1988). Were both shocks of the same magnitude? Did they occur on the same fault system, or could the first shock have triggered the second one on a different fault system? The only thing macroseismic historical information can resolve at this stage is that the overall damage pattern of

damage of the 1356 Basel earthquake sequence resembles that of a single $M_w=6.2$ earthquake, located on an N073°E-striking fault and rupturing a ca. 10-km-thick piece of the crust (Table 2).

7. Summary

The 1356 Basel earthquake is one of the most devastating earthquakes ever felt in intra-plate Europe. Because of this aspect, the seismic parameters derived from this earthquake are used in national regulations for mitigating earthquake hazards.

Up to now, estimations of the maximum damage area of the earthquake relied on the locations given by Müller (1956) of castles names listed by seven different chroniclers. Some of these castles appeared really far from Basel and beyond an area devoid of damages. This is inconsistent with seismic shaking

because shaking is commonly more damaging close to the epicentre. For four of the castles located in Sundgau, the modern association between name and locality is even highly improbable because no damages were reported in these localities.

At first, a thorough analysis of the historical chronicles demonstrated that the most reliable reports were those of Müller (1375) and Appenweiler (1471). This is because they present first hand information and seem to report independent information. The other chronicles were written nearly 200 years after the quake and mostly compiled both early chronicles.

When mapping the sequence of castles listed in Appenweiler's chronicle (1471), it appears that they were enumerated as if following an itinerary. A similar feature is hinted in Müller's (1375) castle inventory, if the alleged Sundgau castles are overlooked.

We suggest new plausible locations for the castles that appeared far from the rest of the sequence. These new locations are closer to the rest of the itinerary, they are linguistically related to the modern localities and most target localities have castle ruins. With this analysis, it turns out that all Sundgau castles find alternative locations closer to the epicentre, consistently with seismic wave attenuation principles. As a consequence, our new castle locations demonstrate that the strange northern extension of the maximum damage area may just be a mere misinterpretation artefact.

Castle damage distributions were inverted to deduce seismogenic parameters with BOXER, a seismic inversion software retrieving fault parameters from a distribution of observed intensities. The new castle location imply that the 1356 Basel earthquake was slightly less strong than could be modelled with the the initial distribution (6.2 instead of 6.3), conformably to the magnitude suggested by Levret *et al.* (1994). The seismogenic fault is also slightly smaller in size than for the initial damage distribution, but more importantly, the modelled seismogenic fault is striking E-W regardless of the input damage distributions.

8. Conclusion

This work has two important outcomes. Firstly, we sought to test the robustness of damage locations associated with the 1356 Basel earthquake and found that alternative possibilities existed. These alternatives locations are generally supported by historical studies, and above all waived improbable seismological conditions posed by damaged castles isolated far away from the epicentral area. Secondly, we modelled possible seismogenic parameters for the fault having generated the earthquake and obtained a possible fault striking E-W. Future work should attempt to verify whether such structure occur where the model predicts it, and assess whether it could be activated given tectonic boundary conditions.

Acknowledgements

We acknowledge the financial support of the European Union project ENTEC (HPRN-2000-00053), and the partnership with Electricité de France (EDF) and the Institut de Radioprotection et de Sécurité Nucléaire (IRSN) for supporting SisFrance database. Luca Valensise and Pierre Alexandre are gratefully thanked for their valuable comments, suggestions and review, and Monica Gisler for providing historical material. We particularly thankful to Stefan Schmid and Kamil Ustaszewski for many constructive discussions in the last few years.

References

- Appenweiler, E. (1471). Chronik. In "Basler Zusätze zur sächsischen Weltchronik." (A. Bernoulli, Ed.). Basler Chroniken, Leipzig, 1890.
- Burgenkarte der Schweiz. (1976). Blatt 1. Wabern.
- Cassini de Thury, C. F. (1763). Carte levée entre 1759 et 1761 par Capitaine et Pouillard, vérifiée par Cornuau, n°165, feuille 70.
- Closener, F. (1362). Chronik. In "Chroniken der deutschen Städte vom 14 bis in's 16 Jahrhundert." (C. Hegel, Ed.), t. VIII, Basel, 1870.
- Gasperini, P., Bernardini, F., Valensise, G., and Boschi, E. (1999). Defining seismogenic sources from historical earthquake felt reports. Bulletin of the Seismological Society of America 89, 94-110.
- Hauswirth, F. (1971). "Burgen und Schlösser der Schweiz (Basel Landschaft, Basel Stadt, Solothurn)."
- Lambert, J. (1988). "Evaluation de l'aléa sismique du Fossé rhénan. Le tremblement de terre de la région de Bâle, d'octobre 1356." , Orleans.
- Levret, A., Backe, J. C., and Cushing, M. (1994). Atlas of macroseismic maps for french earthquakes with their principal characteristics. Natural Hazards 10, 19-46.
- Mayer-Rosa, D., and Cadiot, B. (1979). Review of the 1356 Basel earthquake: basic data. Tectonophysics 53, 325-333.
- Meghraoui, M., Delouis, B., Ferry, M., Giardini, D., Huggenberger, P., Spottke, I., and Granet, M. (2001). Active normal faulting in the Upper Rhine Graben and palaeoseismic identification of the 1356 Basel earthquake. Science 293, 2070.
- Mercator, G. (1630). Alsace. appud I. Ianssonium, Amsterdam.
- Meyer, B., Lacassin, R., Brulhet, J., and Mouroux, B. (1994). The Basel 1356 earthquake: which fault produced it? Terra Nova 6, 54-63.
- Meyer, W. (1981). "Burgen von A bis Z." Burgenlexikon der Regio, Basel.
- Meyer, W. (1990). Das Basler Erdbeben von 1356 und die angerichteten Schäden. Unsere Kunstdenkmäler 41, 162-168.
- Müller, C. A. (1956). Die Burgen in der Umgebung von Basel und das Erdbeben von 1356. Historische Gesellschaft zu Basel 748.
- Müller, E. (1375). Jahrbuch. In "Mittheilungen der Antiquarischen Gesellschaft." , Zürich, 1844.

- Münster, S. (1544). Chronik. In “Das Erdbeben von 1356 in der Nachrichten der Zeit.” (E. Wackernagel, Ed.), Basel, 1856.
- Sanson, N. (1703). *L'Alsace ou conquête du Roy, en Allemagne, tant deçà que delà le Rhein. Avec les Estats de Souabe, scitués sur le Rhein, possédés tant par la maison d'Autriche, que par le Marquis de Bade.* Pierre Mariette, Paris.
- Scholoder, W. (1525). Chronik. In “Das Erdbeben von 1356 in der Nachrichten der Zeit.” (E. Wackernagel, Ed.), Basel, 1856.
- Stumpff, J. (1548). Chronik. In “Das Erdbeben von 1356 in der Nachrichten der Zeit.” (E. Wackernagel, Ed.), Basel, 1856.
- Tschudi, G. (1570). Chronik. In “Das Erdbeben von 1356 in der Nachrichten der Zeit.” (E. Wackernagel, Ed.), Basel, 1856.
- Ustaszewski, K., Schumacher, M. E., and Schmid, S. M. (submitted). Contemporaneous faulting and extensional flexuring during Palaeogene rifting - a case study from the southern Upper Rhine Graben. *International Journal of Earth Sciences*.
- von Nuwenburg, M. (1368). Chronik. In “*Monumenta Germaniae Historica, Scriptorum Rerum Germanicarum.*” (A. Hofmeister, Ed.). Nova series, Berlin, 1924.
- Wechsler, E. (1987). “Das Erdbeben von Basel 1356. Historische und Kuntshistorische Aspekte.” ETH Zürich, Zürich.
- Wells, D. L., and Coppersmith, K. J. (1994). New empirical relationships among magnitude, rupture length, rupture width, rupture area and surface displacement. *Bulletin of the Seismological Society of America* 84, 974-1002.
- Wurtisen, C. (1580). Chronik. In “Das Erdbeben von 1356 in der Nachrichten der Zeit.” (E. Wackernagel, Ed.), Basel, 1856.

9. Appendix 1

Transcriptions of the chronicles of Müller (1375) (A) and Appenweiler (B).

A*Ain gröz erbidem.*

Anno domini MCCCLvi, an Sant Lucas tag zuo herbest, kam diu gröz erbidem, daz vil stett und burg niederfielent und grözger schade beschach.

Des êrsten fiel Bâsel nider und verbran, ez verfiel ouch etwâ vil liutes dar inne. Ez fielent ouch
 30 diu statt zuo Fillach, daz stettli zuo Liestal, diu festi Hônberg, zwô Felsperg, zwô Schowenberg, dri
 vestin, hiezent Wartenberg; ez fielen Kienberg, Varnspurg, Gilgenberg, Münchberg, Löwenberg,
 Hertensperg, Mersperg, Tierstein, Bischofstein, Wildenstein, Niuwen Engenstein, Angenstein, Rîchen-
 stein, Hagenbach, Bronbach, Frôburg, Hasenburg, Landeser, Müstral, Steinbrunnen, Büttingen, Etlî-
 kon, Hertwilen, diu burg zuo Altkilch, zwô Bietkôn, Waldkilch, Brüningen, Guntoltingen, [Fol. 46
 35 a.] Briscgg, Dornegg, Pfeffingen, Sengûr.

B

d) Zur Regierung Karls IV.

¹³⁵⁶ [175^{b1}] In dem 1356 jor von Cristus gebürt kam der vorgeschriben erbidem³⁾ in Tütsche land und sunderlich gon Basel, das die stat verfiel, und das mún- [175^{b2}] -ster⁴⁾ und all kilchen und vil hússer, und bi dryhundert mōnschen. do det der bidem kum als vil schaden als das fûr; das verbrant die hússer, so si vervallen woren. do verfiel ðch vil vestin an dem Blowen⁵⁾. des ersten zwei Schouwenburg⁶⁾ und drû Warttenberg⁷⁾, Münchenstein, Rîchenstein, Dornach, Angenstein, Berenvels⁸⁾, Obren Echs⁹⁾. do lag ein frouwe von Frick¹⁰⁾ in kintzbett, und als das hus nei, do viel die kintbetterin mit dem hus herab in die halden uf einen boum, und ir jungfrou und das kind in der wagen, und beschach in allen dryen nût, das ze klagen wer. do verviel ðch Pfeffingen [176¹] und ein kind
 5 in einer wagen¹⁾; des götti was der bischoff von Bassel, der kam mornendes ritten und wolt gon Bassel²⁾. do frogt er, ob sin got wer uskomen; do sprachentz si: nein. do hies er das kind sùchen in der halden; do ward es funden zwüssent zwein grossen steinen und weinet in der wagen. das ward ein wib
 10 und gewan vil kinden³⁾. ðch verfiel Scholberg⁴⁾, Froburg⁵⁾, Klus⁶⁾, Fürstenstein, zwei Lantzchron⁷⁾, Waldek⁸⁾, Biedertal⁹⁾, Landenberg¹⁰⁾, Blochmund.